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Agricultural Memorandum No. 965

Glasshouse Water Requirement Comparison - Lancashire, 1982

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Introduction

The closure of the Experimental Horticultural Station at Fairfield, Lancashire from where the daily integrated readings of total solar radiation were used by ADAS to estimate the glasshouse water requirement for growers, has brought about a requirement for an appraisal of the other options available.

This memorandum assesses these options and presents recommendations on their use.

Sources of Information

a. Solar Radiation

Ideally an on-site measurement of solar radiation should be made, either inside the glasshouse, or outside when a factor for transmissivity of 0.6 to 0.65 would have to be applied (Forsdyke, 1973). The cost of the instrumentation plus the responsibility for maintenance and recording is such that all but the keenest of growers would find this unacceptable.

A satisfactory alternative is to use values from a nearby site, as was the case with Fairfield, but unfortunately the only official site in the area which records daily total solar radiation is at Aughton and the local procedure there is to record directly onto magnetic tape. There is no human intervention so the daily values can only be obtained up to three weeks in arrears. The map (Fig. 1) shows the positions of the places mentioned in the text.

b. Sunshine

Another method which may be employed is to apply correction factors to daily

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sunshine values as detailed by Day (1961) to give an estimate as to the amount of solar radiation received, and hence a figure for the irrigated water needed by the plants. An example of this system is shown in Annex A.

The relationship between sunshine and total solar radiation is well known but no adjustment is made for the diurnal distribution of sunshine. Errors thus caused will on a weekly basis, tend to cancel each other out leaving a figure which is generally reliable.

In a previous comparison at the Efford Experimental Horticultural Station this method was found to give accurate results (Forsdyke).

c. Potential evaporation (PE)

The Meteorological Office produces weekly PE values for a range of crop types throughout the year. The PE figures most readily and quickly available are those calculated for grassland. A previous analysis has compared PE with radiation derived water requirement values (Ingham, 1978). Apart from a few "rogue" values, Ingham considered that the PE data, as produced in the MORECS bulletin (the Met. Office Rainfall and Evaporation Calculation System, Thompson et al, 1981) provided good estimates. Since Ingham's comparison the method of calculation has been altered so his method cannot be repeated on a comparable basis.

Comparison for Lancashire

The techniques of using radiation, sunshine and PE values on which to base a water requirement estimate were tested during the period of 25 March to 22 September 1982 using data obtained from Aughton, Squires Gate (Blackpool airport) and MORECS (grid squares 96 and 97) respectively.

Minor complications in the procedure of the analysis are acknowledged in that Squires Gate and Aughton are, under certain environmental conditions liable to experience quite different weather due solely to their geographical position (see Fig. 1). Further, the week ending dates are not coincident because MORECS ends on a Tuesday while the others end each Wednesday.

The overall effect of the above will produce a greater scatter in the weekly values but over the six month period the deviations will tend to cancel out.

The best estimate for the purposes of this investigation is the Aughton solar radiation data and the other techniques will be assessed relative to this standard.

Sunshine against Radiation

Two methods for calculating the water requirement from sunshine values are considered.

The average evaporation values given in MAFF Technical Bulletin 16 can on a weekly basis be adjusted depending on the ratio of actual to average sunshine for the week, as used by Forsdyke. This gave values which were within $\pm$ 0.02 inches per day ($\pm$ 3.6 l/m^2 per week).

Although since Forsdyke's comparison improved methods for estimating solar radiation from daily sunshine hours have been developed (eg. Cowley, 1978) to give more accurate ways of estimating the energy available in a glasshouse for transpiration, and hence the water requirement, the simpler technique derived by Day (1961) is more suitable if a grower is to maintain his own records.

Table 1 presents the weekly data as calculated from Day's equation, and from there it can be seen that when compared to the calculation based on measured solar radiation there is a small overall bias of -0.82 l/m^2 per week with the weekly values mainly lying between $\pm$ 2 l/m^2 per week.

MORECS against Radiation

For both grid squares a large and systematic bias is evident. In the period up to mid June, the MORECS values were commonly 2 to 8 l/m^2 less than those derived from radiation measurements. After mid June there is a general over estimate of water requirement, ranging up to 6 l/m^2. Overall the two phases tend to cancel each other out leaving a mean difference of + 0.86 to + 1.0 l/m^2 per week. The larger r.m.s. difference reflects the comparative differences more fairly.

The cause of this effect is difficult to quantify as it lies in part in the nature

of the calculation of evaporation. This includes the effects of temperature, windspeed and vapour pressure as well as sunshine. It would be expected that during windy or arid weeks the MORECS value would be relatively higher. Relating the weather to the other elements in table 1 confirms this assumption, where for example the week ending 5 May proved to have windspeeds significantly above average.

The other complication in using the grassland PE values is in the different growth characteristics of the crops. The MORECS grassland values are loosely based on the curve of potential production, giving monthly estimates of green leaf area (LAI) and surface resistance (r_s) to the transfer of water vapour from the plant to the atmosphere. These values combine to form the following net effect.

Table 2. Monthly values of green leaf area and surface resistance - grassland

Month	1	2	3	4	5	6	7	8	9	10	11	12
LAI	2	2	3	4	5	5	5	5	4	3	$2\frac{1}{2}$	2
r_s	87	87	69	57	45	64	64	74	75	78	87	87

Thus, the month with the greatest potential for evaporation from grassland is May, as it is then that the crop canopy has the lowest resistance to water vapour transfer from the plant to the atmosphere. A growing crop of tomatoes in a heated greenhouse will have a markedly different set of characteristics in the more rapid development of green leaf area and leaf posture. The two sets of characteristics appear to be uncompatible.

General Discussion

It has been shown that the use of daily sunshine values can give a more accurate estimate of water requirement in glasshouses than does the MORECS PE value for grassland.

The major reason for this is the unique set of factors which govern the calculation of evaporation in MORECS. If a constant, idealised crop canopy was included in MORECS then the values would be more pertinant to this application.

A set of weekly or monthly correction factors could be prepared for use with the current grassland or bare soil PE values, but in light of the consistant accuracy

shown by the sunshine based method, this would hardly be worthwhile.

One possible improvement in the sunshine hours method would be to base the calculations on sunshine recording closer to the main glasshouse area. This is currently being investigated.

Acknowledgement

The involvement of D A G Jones, ADAS, Preston, in producing the weekly sunshine-based estimates and the assistance of K Hollyhead in the preparation of the tables was appreciated.

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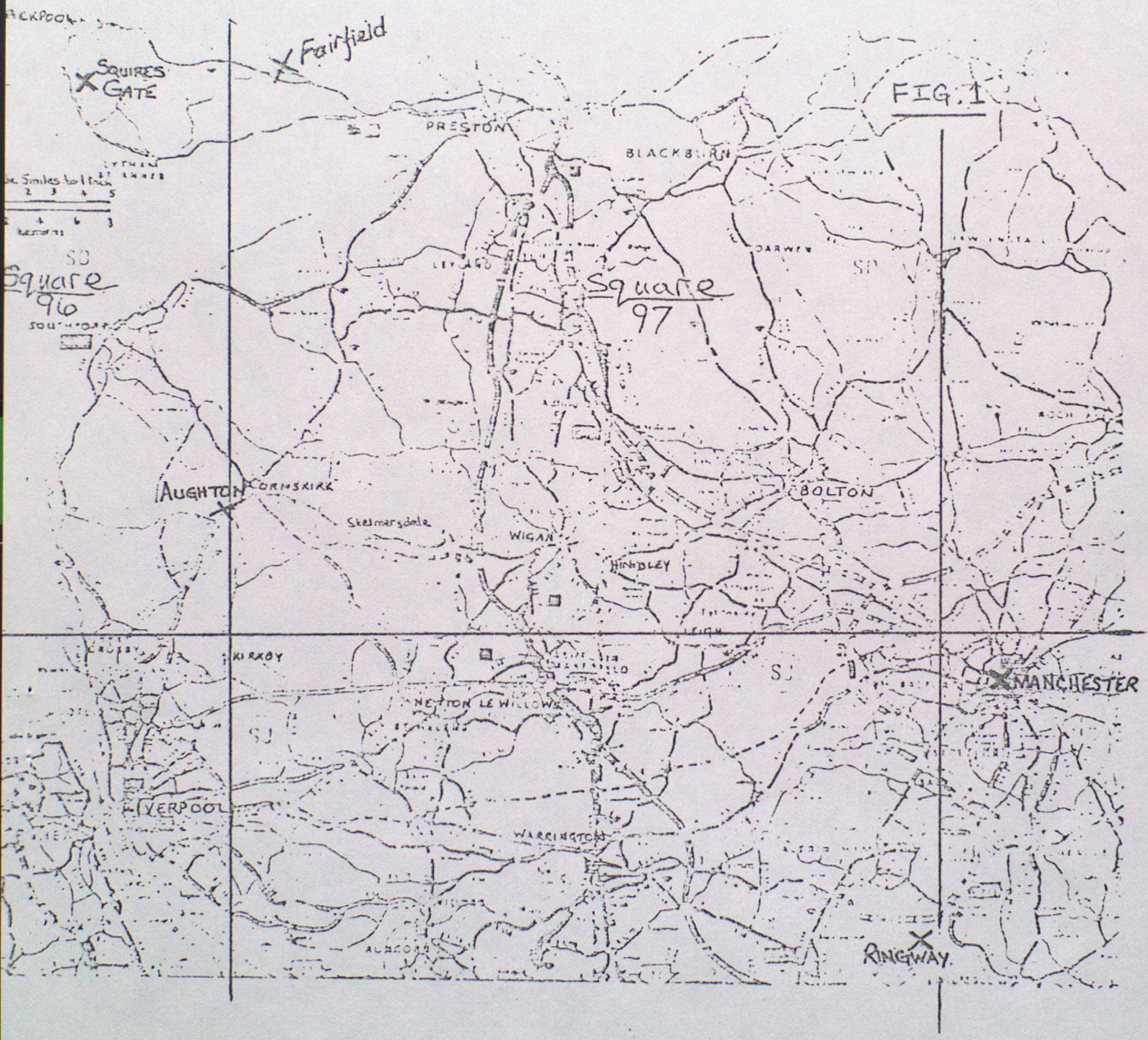
March 1983

Table 1. Weekly total water requirement (l/m^2)

Week Ending	Aughton (by radiation) R	Sq. Gate (by sunshine) S	R-S	MORECS Square 96 M_1	$R-M_1$	MORECS Square 97 M_2	$R-M_2$
31 March	13.6	15.0	-1.4	9.5	4.1	9.5	4.1
7 April	11.1	11.5	-0.4	9.5	1.6	9.5	1.6
14 April	17.7	18.8	-1.1	12.2	5.5	10.9	6.8
21 April	21.7	22.5	-0.8	13.6	8.1	13.6	8.1
28 April	21.1	20.0	1.1	13.6	7.5	13.6	7.5
5 May	17.3	19.1	-1.8	13.6	3.7	17.7	-0.4
12 May	24.3	26.3	-2.0	19.0	5.3	19.0	5.3
19 May	22.0	23.5	-1.5	25.8	-3.8	24.5	-2.5
26 May	15.0	17.7	-2.7	17.7	-2.7	17.7	-2.7
2 June	26.8	27.5	-0.7	23.1	3.7	24.5	2.3
9 June	26.5	25.4	1.1	24.5	2.0	27.1	-0.6
16 June	24.8	24.9	-0.1	20.4	4.4	19.0	5.8
23 June	15.0	16.2	-1.2	17.7	-2.7	14.9	0.1
30 June	19.3	19.9	-0.6	17.7	1.6	17.7	1.6
7 July	20.5	18.4	2.1	19.0	1.5	19.0	1.5
14 July	17.9	17.9	0.0	19.0	-1.1	19.0	-1.1
21 July	21.7	23.6	-1.9	20.4	1.3	20.4	1.3
28 July	20.4	20.6	-0.2	20.4	0.0	19.0	1.4
4 Aug	17.0	17.1	-0.1	17.7	-0.7	19.0	-2.0
11 Aug	13.9	16.8	-2.9	14.9	-1.0	14.9	-1.0
18 Aug	17.5	19.3	-1.8	23.1	-5.6	21.7	-4.2
25 Aug	12.7	12.2	0.5	19.0	-6.3	19.0	-6.3
1 Sept	16.2	16.1	0.1	19.0	-2.8	19.0	-2.8
8 Sept	13.9	12.7	1.2	13.0	0.9	13.0	0.9
15 Sept	13.0	10.9	2.1	11.0	2.0	12.0	1.0
22 Sept	11.6	11.1	0.5	12.0	-0.4	13.0	-1.4
Mean difference			-0.82		+0.93		+0.86
r.m.s. difference			1.41		3.78		3.68


Fairfield
SQUIRES GATE
PRESTON
BLACKBURN
FIG. 1
SD
Square
96
SOUTHPORT
Square
97
SD
AUGHTON
ORMSKIRK
Skelmersdale
WIGAN
HINDLEY
BOLTON
KIRKBY
SJ
NEWTON LE WILLOWS
MANCHESTER
VERPOOL
WARRINGTON
RINGWAY

ANNEXE A WATER REQUIREMENT CALCULATION USING DAILY HOURS OF SUNSHINE

The basic equation is

$$R = Rx\ (a + b\ (^{n}/_{N}))$$

where R = the solar radiation incident on the glass

Rx = the maximum possible radiation value, assuming a clear atmosphere

n = the daily sunshine, in hours

N = the day length, in hours

a and b are constants which depend on month and site.

Units of Rx are normally expressed in W. hr. m^{-2} and for June in Lancashire a value of 11745W.hr.m^{-2} is used. For water requirement calculations it is preferable to convert the units into mm of water per day, after giving regard to the fractions of the solar beam which are transmitted through the glass and utilised in transpiration.

$$Rw = \frac{(Rx)(Ft)(Fu)(T)}{L}$$

where Rw is the converted value, now in mm /day

Ft = the fraction transmitted (= 0.6)

Fu = " " utilised (= 0.7)

T = time (seconds in one hour = 3600)

L = latent heat of water to water vapour = 2.45×10^{6} J/kg

giving $Rw = 617 \times 10^{-6}\ Rx$

For the week ending 16/6/82 the following daily sunshine hours were recorded: 2.2, 9.9, 6.1, 10.7, 15.2, 0.0, 13.6. The mean daily value is therefore 8.24 hours (the mean day length = 17.1 hours).

To calculate the mean daily water requirement for that week we have

$$R = (617 \times 10^{-6})\ (11745)\ (0.25 + 0.54\ (\frac{8.24}{17.1}))$$

$$= 3.70 \text{ mm per day}$$

or 25.9 mm for week.

Note:

Values of Rx, a, b, n, N all vary by either month or area. The Regional Meteorological Office can provide relevant values for any particular site.